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DEVICE AND METHOD FOR CONTROLLING SEMICONDUCTOR LASER MODULE

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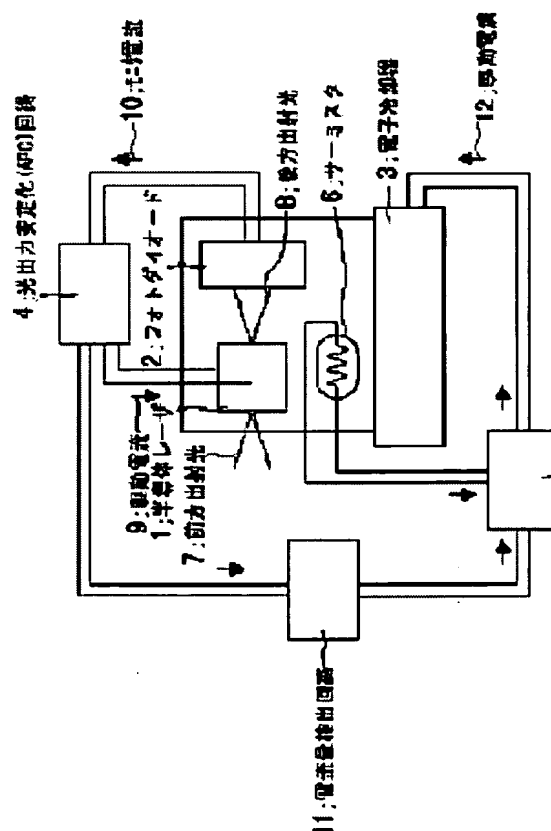
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Abstract of JP2000323785

PROBLEM TO BE SOLVED: To provide a device and method for controlling semiconductor module by which the variation of the oscillating wavelength of a semiconductor laser caused by temperature fluctuation can be prevented, by controlling the temperature of the laser so that the actual temperature of the laser may be fixed even when the driving current of the laser increases due to the deterioration of the laser. **SOLUTION:** A controller for semiconductor laser module is provided with a current quantity detecting circuit 11 which is connected to a light output stabilizing circuit that controls the driving circuit of a semiconductor laser based on the output of a photodiode 2 which detects the intensity of the output light of the laser, and a temperature control circuit which drives an electronic cooler that cools the laser based on a thermistor 6 installed to the vicinity of the laser and detects the driving current outputted from the light output stabilizing circuit. The controller sets the driving current of the electronic cooler so as to fix the actual temperature of the semiconductor laser by comparing the measured data of the actual temperature of the laser with respect to the driving current of the laser, the information on the driving current of the laser outputted from the circuit 11, and temperature information outputted from the thermistor 6.

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Description of corresponding document: US6393041

FIELD OF THE INVENTION

[0002] The present invention relates to an apparatus and method for controlling a semiconductor laser module.

BACKGROUND OF THE INVENTION

[0003] The explosive popularization of the Internet has been accompanied by a remarkable increase in transmission capacity needed for backbone systems. The importance of high-density wavelength multiplexing optical-fiber transmission in terms of raising transmission capacity is growing and semiconductor lasers used in such optical-fiber transmission require both stable optical power and wavelength.

[0004] Conventionally, semiconductor lasers used in such fields as optical communications and optical measurement emit light in two directions. The light in one direction is sensed by a photodiode and the driving current of the semiconductor laser is controlled so as to render constant the amount of current through the photodiode, thereby stabilizing the light emitted in the other direction. This makes it possible to exercise control to increase the driving current of the semiconductor laser and the strength of the output light constant even if the semiconductor laser deteriorates with time.

[0005] Owing to the passage of driving current through the semiconductor laser, the temperature thereof rises and the refractive index of the semiconductor laser element increases, thereby causing the lasing wavelength to shift toward the long-wavelength side. A method often employed to solve this problem includes disposing a thermistor on the carrier of the semiconductor laser to sense temperature and cooling the semiconductor laser by an electronic cooling device using a Peltier element.

[0006] An apparatus of this kind for controlling a semiconductor laser module will be described with reference to FIG. 3.

[0007] FIG. 3 is a block diagram illustrating an example of the prior art in which an automatic power control (APC) circuit 4 and an automatic temperature control (ATC) circuit 5 are connected to a semiconductor laser module.

[0008] The APC circuit 4, which is for rendering constant the optical output power of a semiconductor laser 1, will be described first.

[0009] The semiconductor laser 1 emits laser beams from both ends in directions extending to the right and left in FIG. 3. Backward-emitted light 8 on the right side is used to exercise control in such a manner that the output power of forward-emitted light 7 on the left side is rendered constant. The backward-emitted light 8 is received by a photodiode 2 and photoelectrically converted to a monitor current 10, which is then input to the APC circuit 4. The latter controls a laser driving current 9, and outputs it to the semiconductor laser 1, so as to render the value of the monitor current 10 constant, thereby rendering constant the forward-emitted light 7. In other words, the laser driving current 9 is controlled in such a manner that the intensity of the light is rendered constant regardless of the wavelength of the laser emission.

[0010] The ATC circuit 5 for controlling the temperature of the semiconductor laser 1 will be described next.

[0011] A thermistor 6 is placed on the carrier in close proximity to the semiconductor laser 1 in order to sense the temperature of the semiconductor laser 1. The ATC circuit 5 senses the resistance value of the thermistor 6 and passes a driving current to an electronic cooling device 3 in such a manner that the resistance value attains a reference resistance value, thereby holding the temperature of the semiconductor laser 1 constant.

[0012] More specifically, the ATC circuit 5 passes the driving current 12 through the cooling device 3 in a direction that heats the thermistor 6 if the temperature sensed by the thermistor 6 is higher than a set temperature, and passes a current in a direction that cools the thermistor 6 if the temperature sensed thereby is lower than the set temperature. The ATC circuit 5 controls the temperature in such a manner that the value of the passed current increases if the difference between the sensed temperature and the set temperature is large and decreases if the temperature difference is small. Thus, the ATC circuit 5 exercises control in such a manner that the temperature of semiconductor laser 1 remains constant independently of the output power of the semiconductor laser 1, i.e., independently of the magnitude of the laser driving current 9.

[0013] Accordingly, the APC circuit 4 controls the laser driving current 9 in such a manner that the monitor current 10 of the photodiode 2 remains constant even if a change in the temperature of the semiconductor laser 1 is accompanied by a change in the wavelength characteristic of the output light. The APC circuit 4 thus operates so as to hold the intensity of the output light constant. On the other hand, the ATC circuit 5 causes the cooling device 3 to operate independently of the APC circuit 4 so that the temperature of the semiconductor laser 1 is constant, regardless of the magnitude of the laser driving current 9, if the temperature of the semiconductor laser unit varies.

SUMMARY OF THE DISCLOSURE

[0014] However, the following problems have been encountered in the course of investigation toward the present invention. Namely, the conventional control apparatus of this construction for controlling a semiconductor laser module has a certain drawback relating to a shift in wavelength. Specifically, when the semiconductor laser 1 begins to age, the lasing threshold value current increases and there is a corresponding increase in the laser driving current 9 for obtaining the desired optical output power, the actual rise in the temperature of the semiconductor laser 1 and the reading (value) of the temperature of the thermistor 6 are no longer the same owing to the existence of a thermal resistance between the semiconductor laser 1 and the carrier part on which the thermistor 6 is placed. Even if the temperature of the thermistor 6 is held constant, therefore, the semiconductor laser 1 assumes a temperature higher by an amount commensurate with the value of the thermal resistance. As a result of this higher temperature, the lasing wavelength of the semiconductor laser 1 is shifted toward the side of longer wavelengths owing to a change in index of refraction.

[0015] This problem associated with the rise in the temperature of the semiconductor laser 1 that accompanies the change in laser driving current 9 is particularly significant in high-density wavelength-multiplexing optical communication. The result is that the change in wavelength accompanying the temperature rise of the semiconductor laser 1 causes crosstalk and a decrease in reception sensitivity, thereby degrading the transmission characteristics.

[0016] Accordingly, an object of the present invention is to provide an apparatus and method for controlling a semiconductor laser module wherein even if laser driving current increases owing to aging of the semiconductor laser, temperature control can be performed accurately so as to render constant the actual temperature of the semiconductor laser and prevent a change in lasing wavelength that accompanies a change in temperature.

[0017] According to a first aspect of the present invention, the foregoing object is attained by providing an apparatus for controlling a (e.g., semiconductor) laser module, comprising: a laser (particularly semiconductor laser), an optical sensor

sensing optical intensity of the laser; optical-power stabilizer for controlling driving current of the semiconductor laser in accordance with an output from the optical sensor; a temperature sensor disposed in the proximity of the laser for sensing temperature thereof; temperature controller for driving an electronic cooling device, which cools the semiconductor laser in accordance with an output from the temperature sensor; and a module of predicting actual temperature of the laser from information indicative of the driving current of the laser and temperature information output from the temperature sensor.

[0018] According to a second aspect of the present invention, the foregoing object is attained by providing an apparatus controlling a (e.g., semiconductor) laser module, comprising: a laser (particularly semiconductor laser), an optical sensor sensing optical intensity of the laser; optical-power stabilizer for controlling driving current of the semiconductor laser in accordance with an output from the optical sensor; a temperature sensor placed in the proximity of the laser for sensing temperature thereof; temperature controller for driving an electronic cooling device, which cools the laser, in accordance with an output from the temperature sensor; and a current-quantity sensor, which is connected to the optical-power stabilizer and temperature controller, for sensing the driving current of the laser output from the optical-power stabilizer; wherein data obtained by actual measurement of actual temperature of the laser in relation to the driving current of the laser is stored in the temperature controller in advance, and the driving current of the cooling device is set upon comparing the data obtained by actual measurement, laser driving current information output from the current-quantity sensor, and temperature information output from the temperature sensor.

[0019] According to a third aspect of the present invention, the foregoing object is attained by providing a method of controlling a (e.g., semiconductor) laser module wherein driving current of a laser (particularly semiconductor laser), is controlled by an optical-power stabilizer on the basis of an output from an optical sensor which senses optical intensity of the laser, and an electronic cooling device for cooling the laser is driven by a temperature controller on the basis of an output of a temperature sensor placed in the proximity of the laser. The method comprises: previously storing, in the temperature controller, data obtained by actual measurement of actual temperature of the laser in relation to the driving current of the laser when the electronic cooling device is driven; comparing the data obtained by actual measurement, laser driving current information output from the optical-power stabilizer and temperature information output from the temperature sensor; and driving the electronic cooling device on the basis of the comparison in such a manner that the actual temperature of the laser is rendered constant.

[0020] Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. 1 is a block diagram schematically illustrating the construction of an apparatus for controlling a semiconductor laser according to a preferred embodiment of the present invention;

[0022] FIG. 2 is a characteristic diagram in which laser module temperature is plotted against the value of laser driving current when lasing wavelength is held constant; and

[0023] FIG. 3 is a block diagram showing the construction of an apparatus for controlling a semiconductor laser in accordance with the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] A preferred mode for practicing the present invention will now be described.

[0025] As shown in FIG. 1, an apparatus for controlling a semiconductor laser 1 according to a preferred mode for practicing the present invention includes a photodiode 2 for sensing optical intensity of the semiconductor laser 1; an optical-power stabilizing circuit 4 for controlling driving current of the semiconductor laser 1 in accordance with an output from the photodiode 2; a thermistor 6 placed in the proximity of the semiconductor laser 1 for sensing the temperature thereof; a temperature control circuit 5 for driving an electronic cooling device, which cools the semiconductor laser 1, in accordance with an output from the thermistor 6; and a current-quantity sensing circuit 11, which is connected to the optical-power stabilizing circuit 4 and temperature control circuit 5, for sensing the driving current of the semiconductor laser 1 output from the optical-power stabilizing circuit 4. Data obtained by actual measurement of actual temperature of the semiconductor laser 1 in relation to driving current of the semiconductor laser is stored in the temperature control circuit 5 in advance. The data obtained by measurement, laser driving current information output from the current-quantity sensing circuit 11 and temperature information output from the thermistor are compared (e.g., by data processing) and the driving current of the cooling device is set, based upon the result of the comparison, in such a manner that the actual temperature of the semiconductor laser is rendered constant.

[0026] A preferred embodiment of the present invention will now be described in greater detail with reference to FIGS. 1 and 2, in which FIG. 1 is a block diagram useful in describing the construction of an apparatus for controlling a semiconductor laser module according to a preferred embodiment of the present invention, and FIG. 2 is a diagram showing the relationship between laser temperature and laser current.

[0027] The construction of the apparatus for controlling the semiconductor laser module according to this embodiment will be described first.

[0028] As shown in FIG. 1, the apparatus includes a photodiode 2 for sensing backward-emitted light from a semiconductor laser 1; an APC (automatic power control) circuit 4 which, on the basis of a monitor current 10 from the photodiode 2, senses the optical output power of the semiconductor laser 1 at a desired optical output power level; a thermistor 6 for sensing temperature of the semiconductor laser 1; a cooling device 3 for cooling the semiconductor laser 1; and an ATC (automatic temperature control) circuit 5 for controlling a driving current 12 of a cooling device 3. According to a characterizing feature of this embodiment, the current-quantity sensing circuit 11 is connected to the APC circuit 4 and ATC circuit 5.

[0029] Further, according to the characterizing feature of this embodiment, data obtained by actual measurement of the temperature of the laser in response to the driving current of the laser is stored beforehand in the current-quantity sensing circuit 11, which senses the value of the laser driving current 9, and this data is used to control the ATC circuit 5 to stabilize the

wavelength of the semiconductor laser 1.

[0030] The APC circuit 4, which is for rendering constant the optical output power of the semiconductor laser 1, will be described first.

[0031] The semiconductor laser 1 emits laser beams from both ends in directions extending to the right and left in FIG. 1 backward-emitted light 8 on the right side is used by the APC circuit 4 to exercise control in such a manner that the optical power of forward-emitted light 7 on the left side is rendered constant. The backward-emitted light 8 is received by the photodiode 2 and photoelectrically converted to a monitor current 10, which is then input to the APC circuit 4. The latter controls the laser driving current 9, which is output to the semiconductor laser 1, so as to render the value of the monitor current 10 constant, thereby rendering constant the forward-emitted light 7.

[0032] Wavelength stabilizing module (the current-quantity sensing circuit 11 and ATC circuit 5) for controlling the wavelength of the semiconductor laser 1, which constitutes a feature of this embodiment, will be described next.

[0033] In the conventional apparatus for controlling a semiconductor laser module, the APC circuit 4 and ATC circuit 5 control independently of each other and temperature is controlled, irrespective of the value of the laser driving current 9, in a manner that the temperature of the thermistor 6 is rendered constant. Consequently, even when the semiconductor laser is lasing, the lasing threshold-value current increases and there is an increase in the driving current 9, the ATC circuit 5 operates in accordance solely with a reading (value) of the temperature rise of thermistor 6.

[0034] However, there is thermal resistance between the semiconductor laser 1 and thermistor 6, and thus, the actual value of the rise in the temperature of the semiconductor laser 1 does not correspond perfectly to the reading (value) of the temperature at the thermistor 6. As a consequence, the actual temperature of the semiconductor laser 1 cannot be held constant with the conventional method and, hence, the lasing wavelength fluctuates owing to a change in the refractive index of the semiconductor laser 1.

[0035] By contrast, in accordance with this embodiment, information indicative of the driving current 9 applied to the semiconductor laser 1 from the APC circuit 4 is output to the current-quantity sensing circuit 11. This information concerning the driving current 9 is transmitted to the ATC circuit 5. The latter predicts the amount of rise in the temperature of the semiconductor laser 1 by referring to the actual-measurement data, which indicates laser temperature versus driving current stored previously in this circuit. By comparing this predicted value with information representing the ambient temperature of the semiconductor laser 1 sent from the thermistor 6, the ATC circuit controls the driving current 12 sent to the cooling device 3 in such a manner that the actual temperature of the semiconductor laser 1 is rendered constant.

[0036] The relationship between the driving current 9 of semiconductor laser 1 and temperature thereof stored in the ATC circuit 5 will be described with reference to FIG. 2.

[0037] FIG. 2 is a characteristic diagram in which laser module temperature is plotted against the value of laser driving current 9 when lasing wavelength of the semiconductor laser 1 is held constant. The characteristic shown in FIG. 2 is measured in advance and then stored in the ATC circuit 5. Before the driving current 9 of the laser changes, the resistance value of the thermistor 6 is detected and a current is passed into the cooling device 3 in such a manner that the sensed resistance value becomes equal to a reference resistance value, as a result of which the temperature of the semiconductor laser 1 is held constant.

[0038] If the laser driving current 9 varies from an initial current value 10, the amount of change in the driving current 9 is sensed by the current-quantity sensing circuit 11 connected to the APC circuit 4 and this information is transmitted to the ATC circuit 5. On the basis of the characteristic (FIG. 2) measured previously, the ATC circuit 5 drives the cooling device 3 so as to vary the temperature setting of the semiconductor laser 1 from the initial laser temperature T_0 in response to a change in driving current 9. In the case of the characteristic shown in FIG. 2, the ATC circuit 5 drives the cooling device 3 so as to change the laser temperature by 1[deg.] C. if the laser driving current 9 rises by 10 mA from the initial value.

[0039] Thus, according to the apparatus for controlling the semiconductor laser according to this embodiment, the laser driving current 9 from the APC circuit 4, which holds the optical output power of the semiconductor laser 1 constant, is sensed by the current-quantity sensing circuit 11 and information indicative thereof is transmitted to the ATC circuit 5. The latter computes information based upon the previously stored relationship between laser driving current and laser temperature and the temperature information from the thermistor 6 and drives the cooling device 3 in such a manner that the actual temperature of the semiconductor laser 1 is rendered constant. Accordingly, even if thermal resistance (i.e., difference in temperatures) develops between the semiconductor laser 1 and the thermistor 6, the actual temperature of the semiconductor laser 1 can be controlled in an accurate fashion. This makes it possible to prevent a change in laser wavelength associated with a rise in temperature of the semiconductor laser 1.

[0040] Though this embodiment has been described in regard to a case where a semiconductor laser is used as the light-emitting element, the present invention is not limited to this embodiment. Optical power and lasing wavelength can be stabilized simultaneously in the same manner even in the case of a laser module, e.g., an integrated semiconductor laser device obtained by integrating a light-emitting element and a modulator. Further, though the data representing the relationship between the driving current and temperature of the laser is stored in the ATC circuit 5 beforehand in the foregoing embodiment, it goes without saying that this data can be stored in the current-quantity sensing circuit 11 and a comparison can be made between the information concerning the APC circuit 4 and the information concerning the ATC circuit 5.

[0041] Thus, in accordance with the apparatus for controlling a laser module, (particularly, semiconductor laser module) according to the present invention as described above, it is possible to stabilize both the optical output power level and lasing wavelength of a semiconductor laser. This can be achieved because of the operative association between the optical-power stabilizing circuit, which stabilizes the output power of the laser at a desired output power level, and the temperature controlling circuit that controls the temperature of the semiconductor laser. The actually measured data indicative of the relationship between the driving current and temperature of the semiconductor laser is stored beforehand and the actual temperature of the semiconductor laser can be controlled based upon this data, information indicative of the driving current of the laser and information indicative of the ambient temperature of the laser.

[0042] As many apparently widely different embodiments of the present invention can be made without departing from the

and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined by the appended claims.

[0043] It should be noted that other objects, features and aspects of the present invention will become apparent in the entire disclosure and that modifications may be done without departing the gist and scope of the present invention as disclosed herein and claimed as appended herewith.

[0044] Also it should be noted that any combination of the disclosed and/or claimed elements, matters and/or items may be made and the modifications aforementioned.

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Claims of corresponding document: US6393041

What is claimed is:

[0045] 1. An apparatus for controlling a semiconductor laser module, comprising: a semiconductor laser; an optical sensor for sensing optical intensity of the semiconductor laser; optical-power stabilizing means for controlling driving current of the semiconductor laser in accordance with an output from said optical sensor; a temperature sensor disposed in the proximity of the semiconductor laser for sensing the temperature thereof; temperature control means for driving an electronic cooling device which cools the semiconductor laser, in accordance with an output from said temperature sensor; and means for predicting actual temperature of the semiconductor laser from information indicative of the driving current of the semiconductor laser and temperature information output from said temperature sensor.

[0046] 2. An apparatus for controlling a semiconductor laser module, comprising: a semiconductor laser; an optical sensor for sensing optical intensity of the semiconductor laser; optical-power stabilizing means for controlling driving current of the semiconductor laser in accordance with an output from said optical sensor; a temperature sensor disposed in the proximity of the semiconductor laser for sensing the temperature thereof; temperature control means for driving an electronic cooling device which cools the semiconductor laser, in accordance with an output from said temperature sensor; and current-quantity sensing means, which is connected to said optical-power stabilizing means and to said temperature control means, for sensing the driving current of the semiconductor laser output from said optical-power stabilizing means; wherein data obtained by actual measurement of actual temperature of the semiconductor laser in relation to the driving current thereof is stored in said temperature control means in advance, and the driving current of said cooling device is set upon comparing the data obtained by actual measurement, laser driving current information output from said current-quantity sensing means, and temperature information output from said temperature sensor.

[0047] 3. A method of controlling a semiconductor laser module wherein driving current of a semiconductor laser is controlled by an optical-power stabilizer on the basis of an output from an optical sensor which senses optical intensity of the semiconductor laser, and an electronic cooling device for cooling the semiconductor laser is driven by temperature control means on the basis of an output of a temperature sensor placed in the proximity of the semiconductor laser, said method comprising: predicting actual temperature of the semiconductor laser from laser driving current output from said optical-power stabilizer and temperature information output from said temperature sensor.

[0048] 4. A method of controlling a semiconductor laser module wherein driving current of a semiconductor laser is controlled by an optical-power stabilizer on the basis of an output from an optical sensor which senses optical intensity of the semiconductor laser, and an electronic cooling device for cooling the semiconductor laser is driven by a temperature control means on the basis of an output of a temperature sensor disposed in the proximity of the semiconductor laser, said method comprising: previously storing, in said temperature controller, data obtained by actual measurement of actual temperature of the semiconductor laser in relation to the driving current thereof when said electronic cooling device is driven; comparing the data obtained by actual measurement, laser driving current output from said optical-power stabilizer and temperature information output from said temperature sensor; and driving said electronic cooling device based on said comparison in such a manner that the actual temperature of the semiconductor laser is rendered constant.

[0049] 5. A laser apparatus comprising a laser controlling module, comprising: a laser unit; an optical sensor for sensing optical intensity of the laser unit; optical-power stabilizer for controlling driving current of the laser unit in accordance with an output from said optical sensor; a temperature sensor disposed in the proximity of the laser unit for sensing the temperature thereof; temperature controller for driving an electronic cooling device, which cools the laser, in accordance with an output from said temperature sensor; and a circuit predicting actual temperature of the laser unit from information indicative of the driving current of the laser unit and temperature information output from said temperature sensor.

[0050] 6. A laser apparatus of claim 5, wherein said laser unit comprises a semiconductor laser.

[0051] 7. A laser apparatus comprising a laser controlling module, comprising: a laser unit; an optical sensor for sensing optical intensity of the laser unit; optical-power stabilizing circuit for controlling driving current of the laser unit in accordance with an output from said optical sensor; a temperature sensor disposed in the proximity of the laser unit for sensing the temperature thereof; temperature control circuit for driving an electronic cooling device, which cools the laser unit, in accordance with

output from said temperature sensor; and current-quantity sensing circuit, which is connected to said optical-power stabilizing circuit and to said temperature control circuit, for sensing the driving current of the laser output from said optical-power stabilizing circuit; wherein data obtained by actual measurement of actual temperature of the laser unit in relation to the current thereof is stored in said temperature control means in advance, and the driving current of said cooling device is set by comparing the data obtained by actual measurement, laser driving current information output from said current-quantity sensing circuit, and temperature information output from said temperature sensor.

[0052] 8. A laser apparatus of claim 7, wherein said laser unit comprises an integrated semiconductor laser.

[0053] 9. A method of controlling a laser module wherein driving current of a laser is controlled by an optical-power stabilizing means on the basis of an output from an optical sensor which senses optical intensity of the laser, and an electronic cooling device for cooling the laser is driven by a temperature controller on the basis of an output of a temperature sensor placed in proximity of the laser, said method comprising: predicting actual temperature of the laser from laser driving current output from said optical-power stabilizer and temperature information output from said temperature sensor.

[0054] 10. A method of claim 9, wherein said predicting actual temperature of the laser is performed by comparing said driving current output and said temperature information output, both preliminarily stored in a store device.

[0055] 11. A method of claim 10, wherein said store device comprises a temperature control circuit for controlling said cooling device.

[0056] 12. A method of claim 10, wherein said temperature further controls circuit temperature of said temperature sensor.

[0057] 13. A method of claim 10, wherein said store device comprises said temperature control circuit for controlling said cooling device.

[0058] 14. A method of claim 10, wherein said store device comprises a current sensor for said laser driving current.

[0059] 15. A method of claim 9, wherein said laser comprises a semiconductor laser.

[0060] 16. A method of controlling a laser module wherein driving current of a laser is controlled by an optical-power stabilizing means on the basis of an output from an optical sensor which senses optical intensity of the semiconductor laser, and an electronic cooling device for cooling the semiconductor laser is driven by a temperature controller on the basis of an output of a temperature sensor disposed in the proximity of the semiconductor laser, said method comprising: previously storing, in said temperature controller, data obtained by actual measurement of actual temperature of the semiconductor laser in relation to the driving current thereof when said electronic cooling device is driven; comparing the data obtained by actual measurement of the driving current output from said optical-power stabilizer and temperature information output from said temperature sensor; and driving said electronic cooling device based on said comparison in such a manner that the actual temperature of the semiconductor laser is rendered constant.

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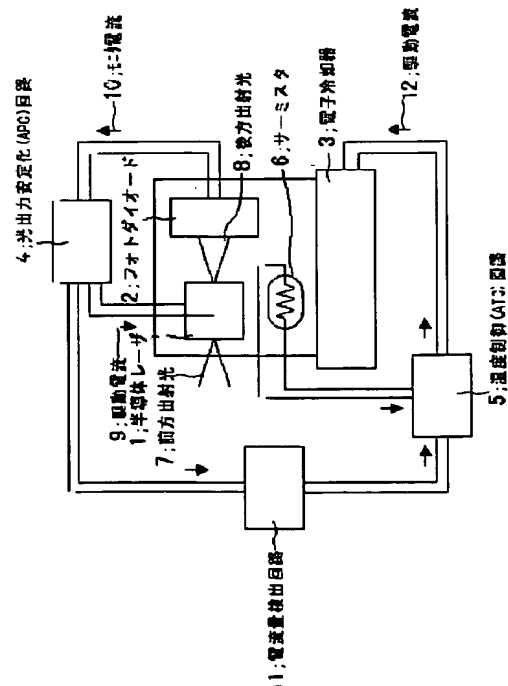
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(54) 【発明の名称】 半導体レーザモジュールの制御装置及びその制御方法

(57) 【要約】 (修正有)

【課題】 半導体レーザが劣化してレーザ駆動電流が増加しても、半導体レーザの実際の温度が一定になるように温度制御し、温度変化に伴う発振波長の変化を防止する半導体レーザモジュールの制御装置と制御方法の提供。

【解決手段】 半導体レーザの光強度を検出するフォトダイオード2からの出力により半導体レーザの駆動電流を制御する光出力安定化回路と、半導体レーザ近傍に設置されるサーミスタ6からの出力により半導体レーザを冷却する電子冷却器を駆動する温度制御回路と、に接続され、光安定化回路から出力されるレーザの駆動電流を検出する電流量検出回路11を有し、温度制御回路に予め記憶された、駆動電流に対する半導体レーザの実際の温度の実測データと、電流量検出回路から出力されるレーザの駆動電流情報と、サーミスタから出力される温度情報とを比較演算し、半導体レーザの実際の温度が一定になるように電子冷却器の駆動電流を設定する。



【特許請求の範囲】

【請求項1】半導体レーザと、該半導体レーザの光強度を検出する光検出器と、該光検出器からの出力により前記半導体レーザの駆動電流を制御する光出力安定化手段と、前記半導体レーザ近傍に設置される温度検出器と、該温度検出器からの出力により前記半導体レーザを冷却する電子冷却器を駆動する温度制御手段と、を少なくとも有する半導体レーザモジュール制御装置において、前記半導体レーザの駆動電流の情報と、前記温度検出器から出力される温度情報とから、前記半導体レーザの実際の温度を予測する手段を設けた、ことを特徴とする半導体レーザモジュール制御装置。

【請求項2】半導体レーザと、該半導体レーザの光強度を検出する光検出器と、該光検出器からの出力により前記半導体レーザの駆動電流を制御する光出力安定化手段と、前記半導体レーザ近傍に設置される温度検出器と、該温度検出器からの出力により前記半導体レーザを冷却する電子冷却器を駆動する温度制御手段と、を少なくとも有する半導体レーザモジュール制御装置において、前記光安定化手段と前記温度制御手段とに接続され、前記光安定化手段から出力されるレーザの駆動電流を検出する電流量検出手段を有し、

前記温度制御手段には、レーザの駆動電流に対する前記半導体レーザの実際の温度を実測したデータを予め記憶し、該実測データと、前記電流量検出手段から出力されるレーザの駆動電流情報と、前記温度検出器から出力される温度情報とを比較演算し、前記電子冷却器の駆動電流を設定する、ことを特徴とする半導体レーザモジュール制御装置。

【請求項3】半導体レーザの光強度を検出する光検出器の出力を基に光出力安定化手段で前記半導体レーザの駆動電流を制御し、前記半導体レーザ近傍に設置される温度検出器の出力を基に温度制御手段で前記半導体レーザを冷却する電子冷却器を駆動する半導体レーザモジュールの制御方法において、前記光安定化手段から出力されるレーザの駆動電流と、前記温度検出器から出力される温度情報とから、前記半導体レーザの実際の温度を予測する、ことを特徴とする半導体レーザモジュールの制御方法。

【請求項4】半導体レーザの光強度を検出する光検出器の出力を基に光出力安定化手段で前記半導体レーザの駆動電流を制御し、前記半導体レーザ近傍に設置される温度検出器の出力を基に温度制御手段で前記半導体レーザを冷却する電子冷却器を駆動する半導体レーザモジュールの制御方法において、前記電子冷却器を駆動するに際し、前記温度制御手段にレーザの駆動電流に対する前記半導体レーザの実際の温度を実測したデータを予め記憶し、該実測データと、前記光安定化手段から出力されるレーザの駆動電流と、前記温度検出器から出力される温度情報とを比較演算し、

前記半導体レーザの実際の温度が一定になるように前記電子冷却器を駆動する、ことを特徴とする半導体レーザモジュールの制御方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は半導体レーザモジュールの制御装置及びその制御方法に関する。

【0002】

【従来の技術】インターネットの爆発的な普及にともない、基幹系に必要とされる伝送容量もめざましい勢いで増加している。この大容量化の中で高密度波長多重方式光ファイバ伝送の重要性が増大しており、この光ファイバ伝送に用いられる半導体レーザには、光出力を安定化させることと同時に波長を安定化させることが求められている。

【0003】光通信や光計測器等に用いられる半導体レーザは、従来、半導体レーザから2方向に出射される光のうち片方の光をフォトダイオードで検出して、そのフォトダイオードの電流量が一定になるように半導体レーザの駆動電流を制御して、他方から出射される光を安定化していた。この方法により、半導体レーザが劣化した場合でも、半導体レーザの駆動電流を増加させて出力光の強度を一定に保つように制御することが可能である。

【0004】また、半導体レーザは駆動電流を流すことによって温度が上昇し、半導体レーザ素子の屈折率が大きくなり、発振波長が長波長側にシフトしてしまうため、サーミスタを半導体レーザのキャリアに設置して温度を検出し、ペルチェ素子を用いた電子冷却器で半導体レーザを冷却するという方法が多く用いられている。

【0005】この種の従来の半導体レーザモジュールの制御装置について図3を用いて以下に説明する。図3は、光出力安定化（APC）回路と温度制御（ATC：Automatic Temperature Control）回路を半導体レーザモジュールに接続した従来例を示すブロック図である。

【0006】まず、半導体レーザ1の光出力を一定にするAPC回路4について説明する。半導体レーザ1からは図の左右方向の両端面からビームが出射される。図の右側の後方出射光8は、左側の前方出射光7の出力が一定になるように制御するために使用される。この後方出射光8は、フォトダイオード2で受光され、モニタ電流10に光電変換された後APC回路4に入力される。APC回路4では、モニタ電流10の値が一定になるように半導体レーザ1へ出力するレーザの駆動電流9を制御して、前方出射光7が一定になるようにしている。すなわち、レーザ出射光の波長に関わらず光強度が一定になるようにレーザの駆動電流9を制御している。

【0007】次に、半導体レーザ1の温度制御を行うATC回路5について説明する。サーミスタ6は、半導体レーザ1の温度を検出するために半導体レーザ1近傍の

キャリア部分に配置されている。ATC回路5では、サーミスタ6の抵抗値を検出し、その抵抗値が基準となる抵抗値と等しくなるように電子冷却器3に駆動電流12を流すことによって、半導体レーザ1の温度を一定に保つようにしている。

【0008】すなわち、サーミスタ6で検知された温度が設定温度よりも高い場合には、サーミスタ6を冷却する方向に電子冷却器7に駆動電流12を流し、逆に、検知温度が設定温度より低い場合には、サーミスタ6を加熱する方向に電流を流す。また、検知されたサーミスタ6の温度と設定温度との差が大きい場合には、流す電流の値が大きくなるようにし、温度差が小さい場合には、電流値が小さくなるように温度制御する。このように、ATC回路5では、半導体レーザ1の光出力、すなわち、駆動電流9の大小とは別個独立に、半導体レーザ1の温度が一定になるように制御している。

【0009】従って、APC回路4では、半導体レーザ1の温度変化に伴い出力光の波長特性が変化しても、フォトダイオード2のモニタ電流10が一定になるように駆動電流9を制御して、出力光の強度を一定に保つように動作する。一方、ATC回路5では、半導体レーザユニットの温度が変化した場合、レーザの駆動電流9の大小に関わらず、APC回路4とは別個独立に電子冷却器3を動作させて半導体レーザ1の温度を一定に保つように動作する。

【0010】

【発明が解決しようとする課題】しかしながら、このような構成の従来の半導体レーザモジュール制御装置では、半導体レーザ1が劣化し始めて発振しきい値電流が増加し、それに対応して所望の光出力を得るためのレーザ駆動電流9が増加した場合には、また、サーミスタ6を設置するキャリア部分と半導体レーザ1の間には熱抵抗が存在するために半導体レーザ1の実際の温度上昇と、サーミスタ6の温度上昇指示値とは同じではなく、従って、サーミスタ6の温度を一定に保つても、半導体レーザ1の温度は熱抵抗の分だけ高い状態になり、その温度上昇に伴って半導体レーザ1の発振波長は屈折率の変化により長波長側に変化してしまうという問題がある。

【0011】このような、駆動電流9の変化に伴う半導体レーザ1の温度上昇は、特に、高密度波長多重光通信を行っている場合には大きな問題であり、この半導体レーザ1の温度上昇に伴う波長変化は、クロストークや受信感度の低下の原因となり伝送特性を劣化させることになってしまう。

【0012】本発明は、上記問題点に鑑みてなされたものであって、その主たる目的は、半導体レーザが劣化してレーザ駆動電流が増加した場合においても、半導体レーザの実際の温度が一定になるように正確に温度制御し、温度変化に伴う発振波長の変化を防止することがで

きる半導体レーザモジュールの制御装置及びその制御方法を提供することにある。

【0013】

【課題を解決するための手段】上記目的を達成するために、本発明は、第1の視点において、半導体レーザと、該半導体レーザの光強度を検出する光検出器と、該光検出器からの出力により前記半導体レーザの駆動電流を制御する光出力安定化手段と、前記半導体レーザ近傍に設置される温度検出器と、該温度検出器からの出力により前記半導体レーザを冷却する電子冷却器を駆動する温度制御手段と、を少なくとも有する半導体レーザモジュール制御装置において、前記半導体レーザの駆動電流の情報と、前記温度検出器から出力される温度情報とから、前記半導体レーザの実際の温度を予測する手段を設けたものである。

【0014】本発明は、第2の視点において、半導体レーザと、該半導体レーザの光強度を検出する光検出器と、該光検出器からの出力により前記半導体レーザの駆動電流を制御する光出力安定化手段と、前記半導体レーザ近傍に設置される温度検出器と、該温度検出器からの出力により前記半導体レーザを冷却する電子冷却器を駆動する温度制御手段と、を少なくとも有する半導体レーザモジュール制御装置において、前記光安定化手段と前記温度制御手段とに接続され、前記光安定化手段から出力されるレーザの駆動電流を検出する電流量検出手段を有し、前記温度制御手段には、レーザの駆動電流に対する前記半導体レーザの実際の温度を実測したデータを予め記憶し、該実測データと、前記電流量検出手段から出力されるレーザの駆動電流情報と、前記温度検出器から出力される温度情報とを比較演算し、前記電子冷却器の駆動電流を設定するものである。

【0015】本発明は、第3の視点において、半導体レーザモジュールの制御方法を提供する。該方法は、半導体レーザの光強度を検出する光検出器の出力を基に光出力安定化手段で前記半導体レーザの駆動電流を制御し、前記半導体レーザ近傍に設置される温度検出器の出力を基に温度制御手段で前記半導体レーザを冷却する電子冷却器を駆動する半導体レーザモジュールの制御方法において、前記電子冷却器を駆動するに際し、前記温度制御手段にレーザの駆動電流に対する前記半導体レーザの実際の温度を実測したデータを予め記憶し、該実測データと、前記光安定化手段から出力されるレーザの駆動電流と、前記温度検出器から出力される温度情報とを比較演算し、前記半導体レーザの実際の温度が一定になるように前記電子冷却器を駆動するものである。

【0016】

【発明の実施の形態】本発明に係る半導体レーザモジュール制御装置は、その好ましい一実施の形態において、半導体レーザ(図1の1)と、半導体レーザの光強度を検出するフォトダイオードと、フォトダイオードからの

出力により半導体レーザの駆動電流を制御する光出力安定化回路(図1の4)と、半導体レーザ近傍に設置されるサーミスタと、サーミスタからの出力により半導体レーザを冷却する電子冷却器を駆動する温度制御回路(図1の5)と、光安定化回路と温度制御回路とに接続され、光安定化回路から出力されるレーザの駆動電流を検出する電流量検出回路(図1の11)を有し、温度制御回路には、レーザの駆動電流に対する半導体レーザの実際の温度を実測したデータを予め記憶し、この実測データと、電流量検出回路から出力されるレーザの駆動電流情報と、サーミスタから出力される温度情報とを比較演算し、半導体レーザの実際の温度が一定になるように電子冷却器の駆動電流を設定する。

【0017】

【実施例】上記した本発明の実施の形態についてさらに詳細に説明すべく、本発明の実施例について図1及び図2を参照して以下に説明する。図1は、本発明の一実施例に係る半導体レーザモジュール制御装置の構成を説明するためのブロック図であり、図2は、レーザ温度とレーザ電流の関係を示す図である。

【0018】まず、図1を参照して、本発明の一実施例に係る半導体レーザモジュール制御装置の構成について説明する。本実施例の半導体レーザモジュール制御装置は、半導体レーザ1と、半導体レーザ1の後方出射光を検出するフォトダイオード2と、フォトダイオード2からのモニタ電流10をもとに半導体レーザ1の光出力を所望の光出力レベルに安定化させる光出力安定化(APC)回路4と、半導体レーザ1の温度を検出するサーミスタ6と、半導体レーザ1を冷却する電子冷却器3、及び、電子冷却器3の駆動電流13を制御する温度制御(ATC)回路5を有し、更に、APC回路4とATC回路5とに接続される電流量検出回路11を有する。

【0019】本実施例では、この半導体レーザ1の駆動電流9の値を検出する電流量検出回路11にレーザの駆動電流に対するレーザの温度を実測したデータを予め記憶させ、このデータを用いてATC回路5を制御することにより半導体レーザ1の発振波長の安定化を図ることを特徴としている。

【0020】まず、半導体レーザの光出力を一定にするAPC回路4について説明する。半導体レーザ1からは図の左右方向の両端面からビームが出射される。図の右側の後方出射光8は左側の前方出射光7の出力が一定になるようにするAPC回路4に使用される。後方出射光8は、フォトダイオード2で受光され、モニタ電流10に光電変換されてAPC回路4に入力される。モニタ電流10の値が一定になるようにAPC回路4で半導体レーザ1への駆動電流9を制御して、前方出射光7が一定になるようにしている。

【0021】次に、本実施例の特徴である半導体レーザ1の波長制御を行う波長安定化手段(電流量検出回路1

1及びATC回路5)について説明する。従来の半導体レーザモジュール制御装置では、APC回路4とATC回路5は独立して制御されており、半導体レーザ1の駆動電流9の値に関わらず、サーミスタ6の温度が一定になるように温度を制御している。従って、半導体レーザ1が劣化して発振しきい値電流が増加し、駆動電流9が増加した場合でも、サーミスタ6の温度上昇指示値にのみ従ってATC回路5が動作することになる。

【0022】ところが、半導体レーザ1とサーミスタ6との間には熱抵抗があり、半導体レーザ1の実際の温度上昇値がサーミスタ6の温度上昇指示値とは完全には対応しないために、従来の方法では半導体レーザ1の実際の温度を一定に保つことができず、従って、発振波長が半導体レーザ1の屈折率の変化によって変化してしまう。

【0023】これに対し、本実施例の場合は、APC回路4からの半導体レーザ1への駆動電流9の情報は電流量検出回路11に出力される。この駆動電流9の情報はATC回路5に伝送され、ATC回路5では予め記憶された駆動電流に対するレーザの温度の実測データを参照して半導体レーザ1の温度上昇量を予測する。そして、この予測値とサーミスタ6から送られる半導体レーザ1の環境温度情報を比較演算することによって、半導体レーザ1の実際の温度が一定になるように電子冷却器3に送る駆動電流13を制御する。

【0024】ここで、ATC回路5に予め記憶される半導体レーザ1の駆動電流9と温度との関係を図2を参照して説明する。図2は、半導体レーザ1の発振波長を一定にした場合におけるレーザ駆動電流値に対するレーザ温度の特性例を示す。まず、図2に示す特性を予め測定し、ATC回路5に記憶しておく。レーザの駆動電流9が変化する前の状態では、サーミスタ6の抵抗値を検出し、その抵抗値が基準となる抵抗値と等しくなるように電子冷却器3に電流を流すことによって、半導体レーザ1の温度を一定に保つようにしている。

【0025】レーザ駆動電流9が初期電流値 I_0 から変化した場合には、APC回路4に接続した電流量検出回路11によって駆動電流9の変化量を検出し、その情報をATC回路5に伝達する。ATC回路5では予め測定した図2の特性に基づき、駆動電流9の変化に対して半導体レーザ1の温度設定値を初期レーザ温度 T_0 から変化させるようにATC回路5を駆動させる。図2の特性の場合、例えば、レーザ駆動電流9が初期値から10mA増加した場合は、レーザ温度を1℃低下させるように駆動する。

【0026】このように、本実施例の半導体レーザ制御装置では、半導体レーザ1の光出力を一定に保つAPC回路4からのレーザ駆動電流9を電流量検出回路11で検出し、その情報をATC回路5に伝達し、ATC回路5では、予め記憶したレーザの駆動電流と温度の関係に

基づき演算した情報とサーミスタ6からの温度情報とを比較検討し、半導体レーザ1の実際の温度が一定になるように電子冷却器3を駆動させるため、半導体レーザ1とサーミスタ6との間に熱抵抗がある場合においても、半導体レーザ1の実際の温度を正確に制御することが可能である。従って、半導体レーザ1の温度上昇に伴うレーザ波長の変化を防止することができる。

【0027】なお、本実施例では、発光素子として半導体レーザを用いた場合について説明したが、本発明は上記実施例に限定されるものではなく、発光素子を変調器と集積化した変調器集積化半導体レーザとしても、同様に光出力を安定化することと同時に発振波長を安定化することができる。また、レーザの駆動電流と温度との関係を示すデータをATC回路5に予め記憶するとしたが、データは電流量検出回路11に記憶して、APC回路4の情報とATC回路5の情報を参照して演算しても良いことは当然である。

【0028】

【発明の効果】以上説明したように、本発明の半導体レーザモジュール制御装置によれば、半導体レーザの光出力レベルと発振波長の双方を安定化させることができるという効果を奏する。

【0029】その理由は、本発明の半導体レーザ制御装置は、所望の光出力レベルにレーザの光出力を安定化させる光出力安定化回路と、半導体レーザの温度を制御す

る温度制御回路を相互に関連づけ、半導体レーザの駆動電流と温度との実測データを予め記憶し、このデータとレーザの駆動電流情報と環境温度情報とから半導体レーザの実際の温度を正確に制御することができるからである。

【図面の簡単な説明】

【図1】本発明の一実施例に係る半導体レーザ制御装置の構成を模式的に示すブロック図である。

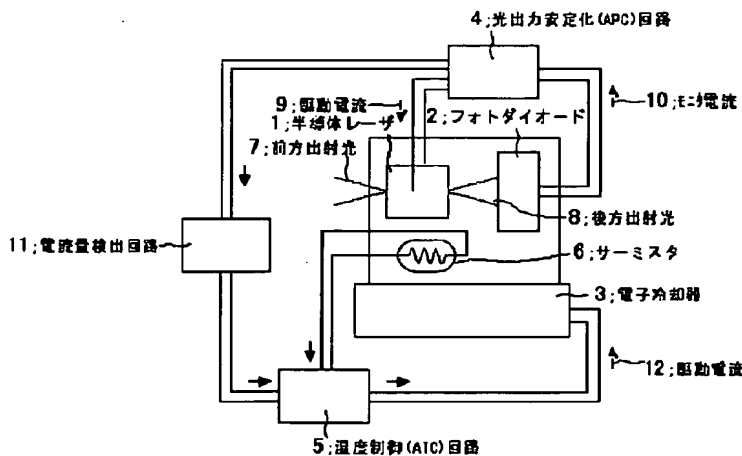
【図2】発振波長を一定にした場合の、レーザ駆動電流値に対するレーザ温度の特性例を示す図である。

【図3】従来の半導体レーザ制御装置の構成を示すブロック図である。

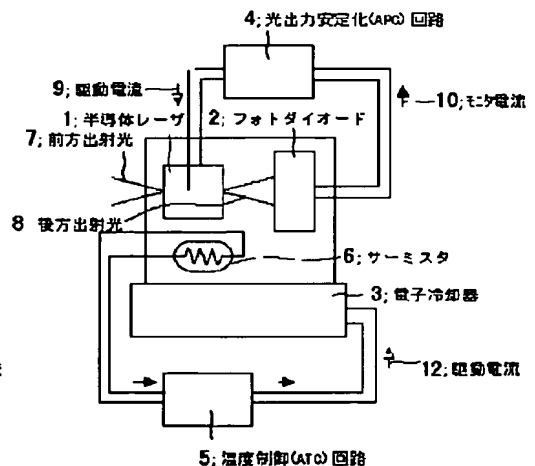
【符号の説明】

- 1 半導体レーザ
- 2 フォトダイオード
- 3 電子冷却器
- 4 APC（光出力安定化）回路
- 5 ATC（温度制御）回路
- 6 サーミスタ
- 7 前方出射光
- 8 後方出射光
- 9 レーザ駆動電流
- 10 モニタ電流
- 11 電流量検出回路
- 12 電子冷却器駆動電流

【図1】



【図3】



【図2】

